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Past perspectives for the future: foundations for sustainable development in East Africa

Rob Marchant [a,*], Paul Lane [b,c]

[a] York Institute for Tropical Ecosystems (KITE), Environment Department, University of York, Heslington, York YO10 5DD, UK
[b] Historical Ecologies of East African Landscapes (HEEAL), Department of Archaeology, University of York, King's Manor, York YO1 7ED, UK
[c] GAES, University of the Witwatersrand, South Africa

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ABSTRACT

East African ecosystems are shaped by long-term socio-ecological interactions with a dynamic climate and increasing human interventions. Whereas in the past these have often been regarded solely in a negative light, more recent research from the perspective of historical ecology has shown that there has often been a strong beneficial connection between people and ecosystems in East Africa. These relationships are now being strained by the rapidly developing and growing population, and their associated resource needs. Predicted future climatic and atmospheric change will further impact on human–ecosystem relationships culminating in a host of challenges for their management and sustainable development, compounded by a backdrop of governance, land tenure and economic constraints. Understanding how ecosystem–human interactions have changed over time and space can only be derived from combining archaeological, historical and palaeoecological data. Although crucial gaps remain, the number and resolution of these important archives from East Africa is growing rapidly, and the application of new techniques and proxies is allowing a more comprehensive understanding of past ecosystem response to climate change to be developed. When used together, it is possible to explore how human and climate change impacts become increasingly enmeshed and so assess interactions within coupled socio-ecological factors such as increased use of fire, changing herbivore densities and increased atmospheric CO_2 concentration. With forecasted environmental change it is imperative that our understanding of past human–ecosystem interactions is queried from the perspective of theories of entanglement to impart effective long term conservation and land use management strategies. Such an approach, that has its foundation in the long term, will enhance possibilities for a sustainable future for East African ecosystems and maximise the livelihoods of the populations that rely on them.

1. Introduction

There is no doubt that the world's environment is changing rapidly and in an unprecedented way. In the relatively short time *Homo sapiens sapiens* has been present on Earth (~200,000 years) there has never been a change in climate, as currently being experienced, from a warm (dry) to warmer (drier) state concomitant with higher concentrations of atmospheric CO_2. Some scholars have argued that the rate of temperature rise and amplitude of orbital forcing now being experienced have their closest analogue during the long interglacial corresponding to Marine Isotope Stage 11 (ca 395–425 kyr BP) (e.g. Loutre and Berger, 2003; Masson-Delmotte et al., 2006), prompting much new palaeoclimatic and palaeoenvironmental research. More recently, however, the suitability of this analogue has been questioned (Dickson et al., 2009). Moreover, while such research may well assist modelling of future ecosystem responses to very rapid increases in temperature and atmospheric CO_2, it can provide insights into how human societies have responded and adapted to such dramatic climate change. Archaeological, historical and palaeoecological perspectives need to be incorporated to enhance the potential for the sustainable use of ecosystems under a future characterised by rapid climate change and increasingly high levels of atmospheric CO_2. Furthermore, exploring how ecosystems respond to increasing global temperatures and rising levels of atmospheric CO_2 concentration, changing precipitation patterns via a series of feedback interactions between solar activity, atmospheric composition, precipitation, land surface conditions and ocean currents on ecosystem composition and distribution would benefit from re-analysis in terms of their historical and ongoing entanglement (Hodder, 2012), as opposed to

* Corresponding author. Tel.: +44 (0) 1904 434061; fax: +44 (0) 1904 432998.
E-mail address: robert.marchant@york.ac.uk (R. Marchant).

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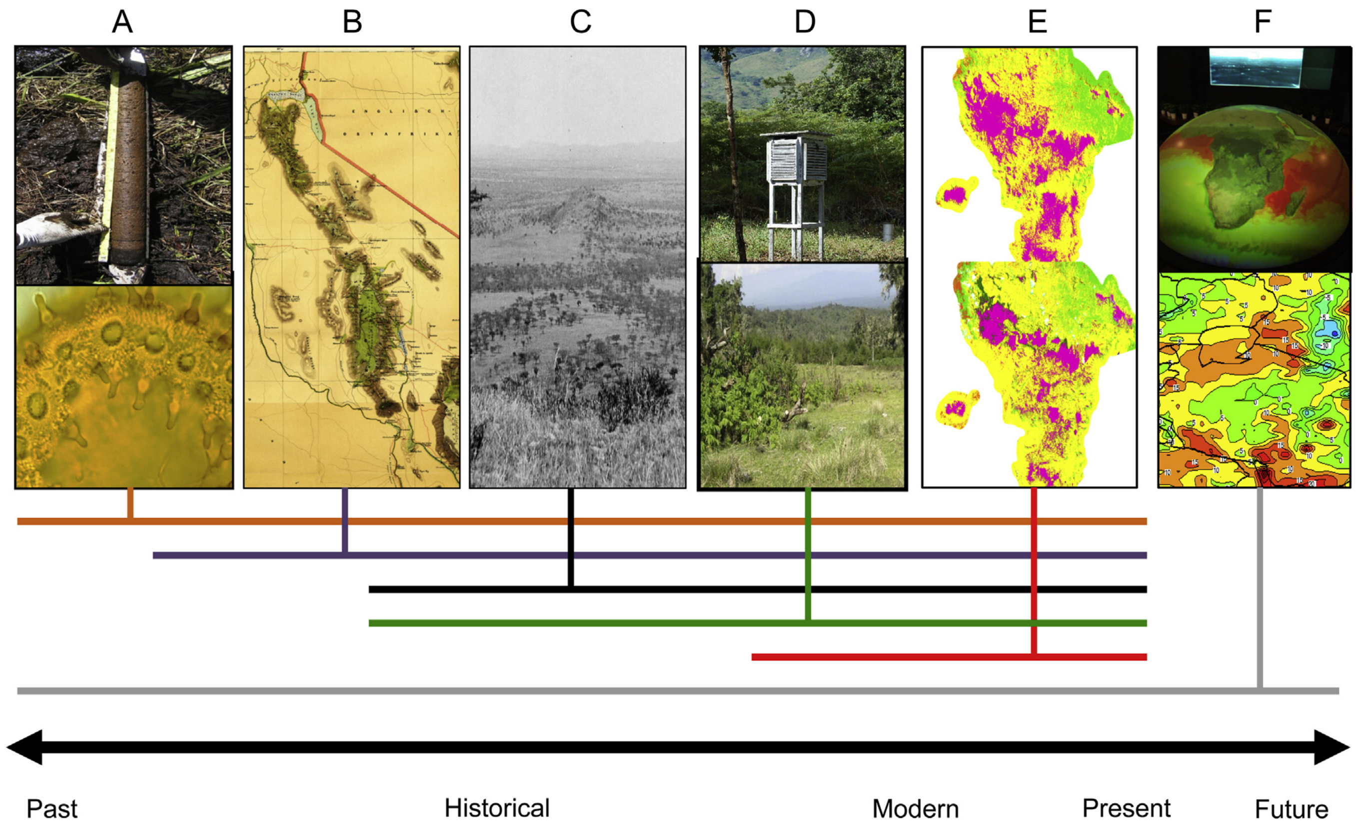

Fig. 1. Scale of investigation and how different environmental proxies combine to reconstruct climate and ecosystem dynamics through time. Accessing deep time is only possible via sedimentary records (A top) where a number of proxy tools such as pollen (A bottom) can be used to place the more recent indicators of environmental ecosystem change in context. Additional sources of information are varied but include historical maps (B), historical photographs (C) archive meteorological data (D top) and assessment of the impact of past land use management on present day species composition (D bottom) and satellite perspective of recently land use change in this case Landsat (1975) (E top) and SPOT (2005) images (E bottom) in context. Such a combined approach is essential to gain a comprehensive understanding of past ecosystem dynamics, human interactions and to engender the development of appropriate and sensitive modelling tools (F) that can be used to understand both the impacts that future climate and socio-development will have and to test some of the findings from the past.

the more conventional attempt to disentangle the relative contributions of different environmental and anthropogenic factors.

To explore these issues, with an aim of developing a roadmap for investigating coupled socioecological systems, we focus here on eastern Africa during the Holocene (with perspectives provided from the last glacial period) as, although humans have been interacting with ecosystems for much longer than the last 10,000 years, these millennia correspond to a significant increase in anthropogenically-dominated ecosystems (Foley et al., 2005; Ellis and Ramankutty, 2008), a trend which, until recently, has been conceptualised almost entirely in terms of an exponential rise in human 'impacts' over time. Yet, much of the newly available palaeoenvironmental research indicates that drought and flood episodes over the Holocene (the past 10,000 years) in East Africa have been much more dramatic, and persistent, than recorded by the instrumental record (Gasse, 2000). As one might expect, there has been much scholarly focus on how societies manage ecosystems in the present, particularly in a conservation context, and may do so in the future. However, the future character of East African ecosystems, given their dynamic ecology, complexity of human–ecosystem interactions and response to atmospheric, climate and land use change is uncertain; that a broader approach to studying past human–ecosystem–environmental interactions is needed with a particular focus on how humans managed and manipulated ecosystems in the past (e.g. Conte, 2010; Stump, 2010). Such a longer temporal focus is aided by a growing awareness, both within scientific and public arenas, about how environmental change impacts on ecosystems, and the human use of these, as the constituent plants and animals adapt to new conditions (Gelorini and Verschuren, 2013) as well as increased recognition of the need to extend the temporal depth of ecological baselines than currently available from observational records.

2. Researching East African palaeoenvironments

How ecosystems have responded to past environmental variability and change has been reconstructed from sedimentary records and to a lesser extent geomorphological signatures. Both are invaluable for studying the past impacts of climate change on natural systems (Willis and Birks, 2006; Willis and Bhagwat, 2010), and East Africa has long been of interest to palaeoecologists (see Marchant and Hooghiemstra (2004), Gelorini and Verschuren (2013), Kiage and Liu (2006) and Tierney et al. (2011) and references therein for details). This palaeoenvironmental research has been fuelled by the wealth of sedimentary deposits that range from ice caps to swamps, from estuaries to lakes, the latter extending from small crater lakes to the large Rift Valley lakes such as Lake Victoria (Fig. 1). Numerous studies reconstructing fluctuating past lake levels (e.g. Beuning et al., 1997; Ryner et al., 2006, 2008; Vincens et al., 2007; Garcin et al., 2007) and vegetation change (Hamilton, 1982; Jolly et al., 1997; Lamb et al., 2003; Gillson, 2004; Taylor et al., 2005) demonstrate the sensitive nature of the East African environment and ecosystems to register change, particularly in response to hydrological (Verschuren et al., 2000, 2009),

fire-ecosystem (Hemp, 2006a), herbivore-ecosystem (Hemp, 2006b; Rucina et al., 2010) and atmospheric CO_2-ecosystem (Jolly and Haxeltine, 1997) interactions.

By combining a range of information about past environments, ecosystems and human populations (Fig. 1) it is possible to develop an excellent understanding of past ecosystem dynamics. As more sedimentary cores recording past environmental variability become available from East Africa (Fig. 2), it is apparent that certain areas and associated ecosystems are more resilient to climate change than others: certain areas have experienced greater degrees of climate change than others. For example, relatively benign past climate changes can be used to explain the exceptional biodiversity of some components via long term persistence of some ecosystems on the Eastern Arc Mountains of Africa (Mumbi et al., 2008; Finch et al., 2009) despite well documented evidence for anthropogenic modification and landscape change in some areas of the mountain chain as reconstructed from soil archives and geomorphological features (Heckmann, 2012). In addition to providing 'observations' about past environments and ecosystems, the palaeoenvironmental perspective provides a benchmark against which to compare present change, and test and constrain future predictions (Braconnot et al., 2007). However, notwithstanding this long history and abundance of suitable sites for palaeoenvironmental research, the records are spatially quite skewed; for example, there are only a couple of records derived from the whole Eastern Arc Mountain range (Mumbi et al., 2008; Finch et al., 2009), while a mass of information exists from Mount Kenya (Coetzee, 1967; Karlen et al., 1999; Barker et al., 2001; Olago, 2001; Ficken, 2001; Ficken et al., 2002; Wooller et al., 2000, 2003; Street-Perrott et al., 2007; Rucina et al., 2009, 2013).

3. From human impacts to constructed environments

Understanding of past human–ecosystem–environmental interactions, and how these have evolved, is crucial for understanding present-day relationships between people and their environments (Robertshaw et al., 2004) and how these combine to form the productive ecosystems of today (Lane, 2011). There is little doubt that the physical, biological and climatic environment has influenced the nature and development of human societies in East Africa, as throughout the world (e.g. Dearing, 2006; Crook et al., 2011). The archaeological record of human societies during the Holocene in eastern Africa is now substantially better known and understood (for overviews see Kusimba and Kusimba, 2003, 2005), allowing for better integration of palaeoenvironmental data than was possible hitherto. Diverse strategies have been followed to develop methodologies suitable for disentangling human–environment–ecosystem interactions, so as to generate well-constrained evidence of complex spatial and temporal connections between archaeological and palaeoecological data in East

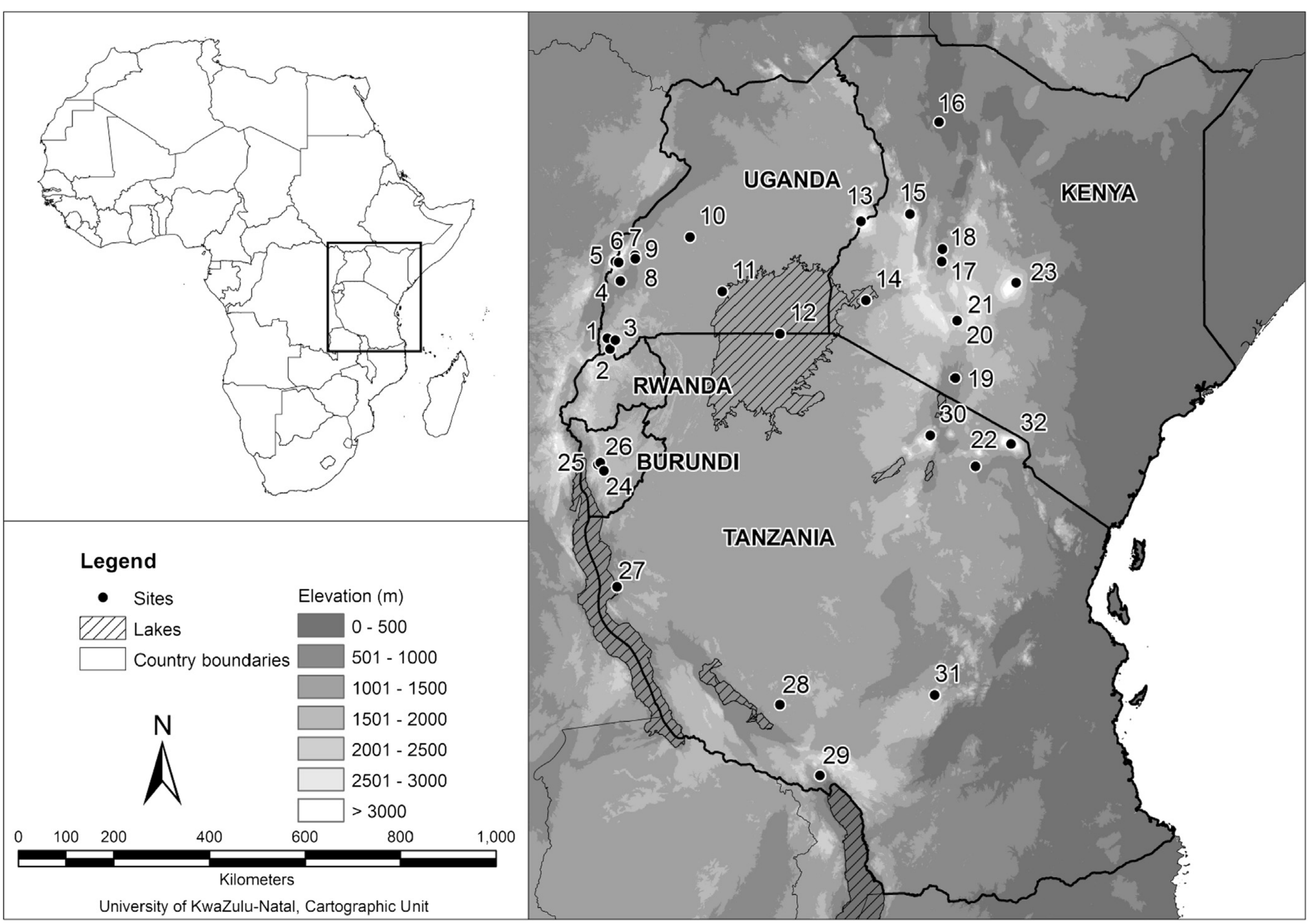

Fig. 2. The East African region depicting the main areas of highland topography and the distribution of palaeoecological sites: 1. Mubwindi Swamp, 2. Muchoya Swamp, 3. Ahakagyezi Swamp, 4. Lake Kitandara, 5. Lake Bujuku, 6. Lake Mahoma, 7. Lake Edward, 8. Kabata Swamp, 9. Lake Wandakara, 10. Munsa, 11. Lake Nabugabo, 12. Lake Victoria, 13. Mt. Elgon, 14. Lake Simbi, 15. Cherangani Hills, 16. Lake Turkana, 17. Loboi Plain, 18. Lake Baringo, 19. Lake Magadi, 20. Crescent Island Crater, Lake Naivasha, 21. Lake Naivasha, 22. Karimu Mire, 23. Mt. Kenya: Lakes Nkunga and Rutundu, Sacred Lake, Rumuiku Swamp, Hausberg, Oblong, Small Hall and Simba Tarns, 24. Kashiru Swamp, 25. Rusaka Peat Bog, 26. Kuruyange Peat Bog, 27. Lake Tanganyika, 28. Lake Rukwa, 29. Lake Masoko, 30. Lake Emakat, Empakaai Crater, 31. Dama Swamp, Eastern Arc Mountains and 32. Mt. Kilimanjaro.

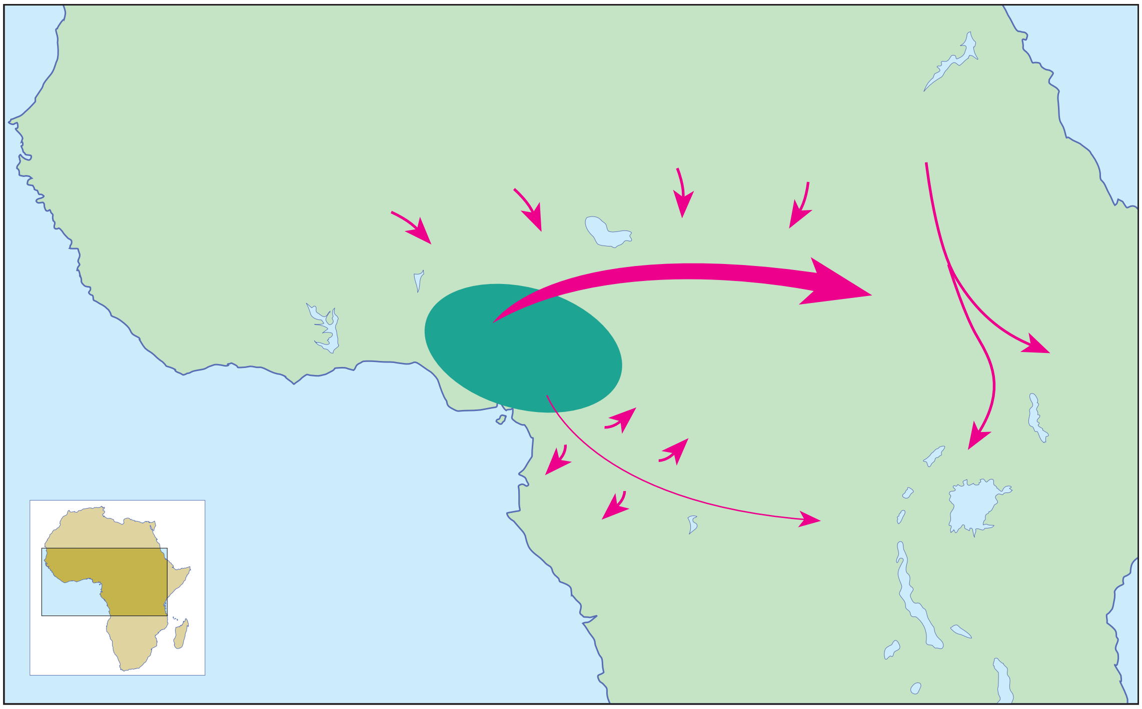

Fig. 3. Bantu Migration routes from the homeland in north-western Africa. Routes are likely to have passed along the Atlantic coastal margins and around and through the Congo basin. On the northern limit this would have traversed the southern limit of the expanding Sahara, then south down the Nile Valley towards the interlacustrine highlands of East Africa.

Africa (Leiju et al., 2005). This interaction is particularly pertinent in East Africa as the environmental and cultural gradients are steep, and hence very sensitive to environmental change. One important step in this process has been placing the archaeological record within the context of detailed and well-dated Holocene palaeoenvironmental records thereby enabling an examination of how societies responded to environmental changes (e.g. Taylor et al., 2005; Ashley et al., 2011). In common with palaeoenvironmental data derived from accumulated sediments, a range of techniques combine to illustrate how human population composition and distribution has changed, and how the interaction with the environment has evolved. This evidence varies from direct analysis of past occupation layers revealed by diverse sources ranging from archaeological investigations to linguistics (e.g. Schoenbrun, 1993), and from molecular markers (e.g. Heller et al., 2008) to documentary evidence (e.g. Endfield et al., 2009). The amount and quality of information is severely skewed towards certain locations and time periods. This also raises several problems, sites with archaeological and palaeoenvironmental data are often not in the same place, and even sites 'close' to each other might record very different signals (Robertshaw et al., 2004). However, the overlap between the response of archaeological and palaeoecological sites can be close as human populations often concentrate within sedimentary basins because of the associated natural resources, in particular water and fertile land for agriculture (Leiju et al., 2005).

There are additional interpretative problems. For instance, it is often assumed, in the absence of direct indicators such as pollen from domesticated plants, that the onset of agriculture is marked by evidence of forest clearance, erosion and burning. This assumption may hold for some activities, but cultivators often make use of natural forest gaps and 'forest' can be promoted by certain forms of cultivation beneath the canopy, for example the Chagga home-gardens around Kilimanjaro (Fernandes et al., 1984; Hemp, 2006c) or the mixed pastoral forest systems on Mount Kenya (Rucina et al., 2013). Although signals may be strong when population levels are relatively high, traces of human activity are not always represented in the sedimentary record – an absence of human indicators does not mean absence in the landscape and there are a number of possible reasons for weak signals of human activity. Some prehistoric societies may have trodden lightly on the landscape, particularly where population densities were low. Subsistence and mobility patterns of pastoralists can leave few traces on land surfaces: pastoralists are typically nomadic (or partially so), residing in areas for only short periods, make widespread use of organic materials for their tools and other artefacts, and may also preferentially curate tools – all leading to low archaeological visibility, and requiring strategies other than conventional foot survey for their detection (e.g. Shahack-Gross, 2011; Shahack-Gross et al., 2008 and references therein).

Aside from these practical challenges, more recent theoretical constructs of human–environment relations, especially from the precepts of historical ecology (Balée, 2006) challenge the notion of human *impacts* and emphasise that disturbance caused by human activities has often played a key role, as in Amazonia (Heckenberger et al., 2003; Erikson, 2006; Arroyo-Kalin, 2010; although cf. Plotkin, 2011), in enhancing the diversity and complexity of specific ecosystems (see also, e.g. McKey et al., 2010; Riede, 2011). Most ecosystems thus need to be understood as 'constructed' (McNiven, 2008) or 'domesticated' (Terrell and Hart, 2008) landscapes in which nature is as much part of the human sphere as humans are of nature. Understanding how these complex ecological relations have evolved is not only critical to understanding contemporary ecological functions and how they might respond to ongoing and future climate change, but also require much closer integration of diverse bodies of data from across the environmental and social sciences and the humanities than is currently customary (Caseldine and Turney, 2010). As part of this there is perhaps a need to consider whether the previous emphasis on trying to disentangle

anthropogenic from natural drivers of environmental change, while having an obvious heuristic value, has in fact obscured the very property of these social-ecological systems that we need to understand rather better – their mutual entanglement.

4. Development of cultural landscapes: agricultural–pastoral–forager interactions

The mid-Holocene in East Africa is characterised by relatively abrupt environmental shifts toward more arid conditions starting from around 5500 cal yr BP (Jolly et al., 1994) when lake levels fell sharply (Stager et al., 1997; Johnson et al., 2000; Vincens et al., 2003), and arboreal pollen percentages declined abruptly reflected by expanding dry forest ecosystems (Ricketts and Johnson, 1996; Wooller et al., 2000). These changes form part of a wider signal culminating about 4000 cal yr BP across the African tropics, with numerous sites recording a shift towards drier environmental conditions that could have precipitated, and certainly influenced, significant shifts in population distribution in Africa, including one that is key to understanding the present population and its associated resource needs – that of the expansion of Bantu language speakers. Once characterised as a large-scale migration (e.g. Oliver, 1966), more recent linguistic (e.g. Vansina, 1995; Ehret, 2001; Blench, 2006), archaeological (Eggert, 2005; Lane et al., 2007) and genetic (e.g. Salas et al., 2002; Berniell-Lee et al. 2009; Pakendorf et al., 2011) studies indicate that complex processes of small scale population migration, settlement and agricultural expansion, language shift, acculturation, exchange and the diffusion of ideas and techniques all contributed to this process to varying degrees at different times and in different parts of the continent. In East Africa, these resulted in complex ethnic and economic mosaics (Kusimba and Kusimba, 2005) and a series of cultural 'frontiers' that varied widely in terms of their permeability, geographical locations and permanence (Lane, 2004; Prendergast, 2011).

One area, the interlacustrine region (Fig. 2), has long been a locus of such cultural and socio-economic changes and a major contact zone between diverse subsistence practices. The transformation to an agro-pastoral lifestyle here is partly associated with the eastward expansion of Bantu language speakers and their associated root crops and agricultural technologies (Fig. 3), rather than independent *in situ* domestication (Schoenbrun, 1993; Holden, 2002). However, the cereal elements of the crop repertoire, were likely domesticated in the Sudanic zone, and possibly as early as ca. 6900–6700 cal. BP for sorghum and 4500–4400 cal. BP for pearl millet (Marshall and Weissbrod, 2011; Manning et al., 2011; Fuller, 2007). Domestic livestock were also introduced into the region via a third route, with their earliest documented presence between ca. 4800–4400 cal. BP occurring initially on herder sites in the Turkana Basin and subsequently on forager sites in the Rift Valley in central Kenya, where fully pastoralist subsistence strategies do not appear until ca. 3500 cal. BP (Prendergast, 2011). Agricultural transformation would have been accompanied by a range of technologies and new crops that would have made the pioneers highly effective at modifying land, in particular clearing forest for agricultural production and supporting a developing iron industry. Although the regional pattern of spread of iron and agricultural practice is controversial (Killick, 2009), the last few thousand years experienced extensive modification of the forested landscape to support an increasingly settled population practicing mixed agriculture (Giblin et al., 2010; Giblin and Fuller, 2011), which may well have triggered soil erosion and morphological landscape change in some localities (Kersting, 2010).

A good example of a 'typical model of agricultural transition' where the arrival of new crops/technology/people results in the sequential transformation from forested to an agricultural

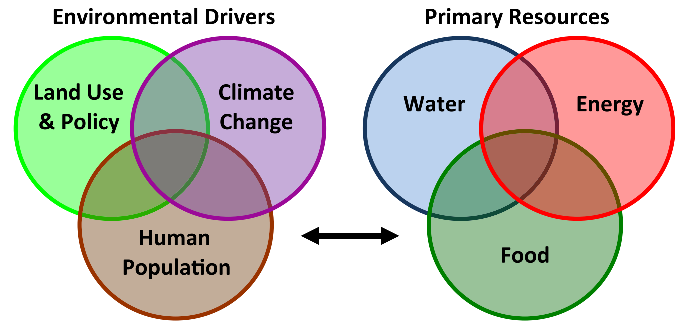

Fig. 4. The three factors of climate change, land use and human population interacting to determine the composition of the ecosystem. These environmental drivers will in turn influence the nature of the plant resource base and the primary economic benefits of plant resources to society: water, energy and food. It is this interaction that needs to be managed for sustainable development, particularly by taking into account the temporal perspectives that palaeoecology can provide.

landscape can be seen in the Rukiga Highlands of south-western Uganda where over forty years of palaeoecological research across six sites covering an altitudinal gradient from 1800 to 2240 m (Morrison, 1968; Hamilton, 1982; Taylor, 1990; Marchant, 2007) has provided an excellent understanding of regional landscape scale ecosystem transformation. To explain the changing regional ecosystem composition and distribution a series of forcing mechanisms (ecological, climatic and human) need to be invoked. It must be stressed that such a 'typical model' is not applicable elsewhere but it does contain common elements of incoming agriculturalists with associated iron technology and crops, resident hunter-gatherer populations, extensive forest clearance, development of densely settled rural populations, with resultant present-day forest remnants restricted to protected areas with sharply defined boundaries (Plate 1). Pollen evidence records quite clearly the replacement of forested areas by open vegetation and degraded scrub from ~2200 cal yr BP (Taylor, 1990). For areas that maintained forest cover, a transition to a more open, and possibly drier, form of forest is apparent from approximately 700 yr BP. This significant spread in forest clearance to lower altitudes was possibly in response to a rapidly growing agricultural population needing to cultivate new land although increased aridity or seasonality will also have influenced forest composition (Marchant, 2007). Despite these major regional land use transitions, a large remnant of extensive montane forest has been maintained that forms the present day Bwindi-Impenetrable Forest National Park (Plate 1). Bwindi-Impenetrable Forest National Park is highly valued today as habitat to a third of the global mountain gorilla population, it is a designated World Heritage site and provides vital ecosystem goods and services to surrounding populations, both through the associated tourist industry, and the collection of forest resources such as medical plants and non-timber forest products within multiple-use collection zones (Cunningham, 1996).

Why this particular patch of forest 'survived' is unknown although it is likely some degree of protection was afforded by the (until recently) resident indigenous hunter-gather, BaTwa populations against incursions by neighbouring communities (Kingdon, 1990). For example, one possibility is that a precursor of Bwindi-Impenetrable Forest corresponded to some form of contested frontier between farmers and hunter–gatherers; the associated instability also placing severe limitations on the development of sedentary agriculture. Certainly, the forest and its associated resources had significant cosmological importance to BaTwa, and as recent research has shown such beliefs may well have found expression in the regional rock art (Namono, 2010). Such a border may also relate to the highly centralised societies in

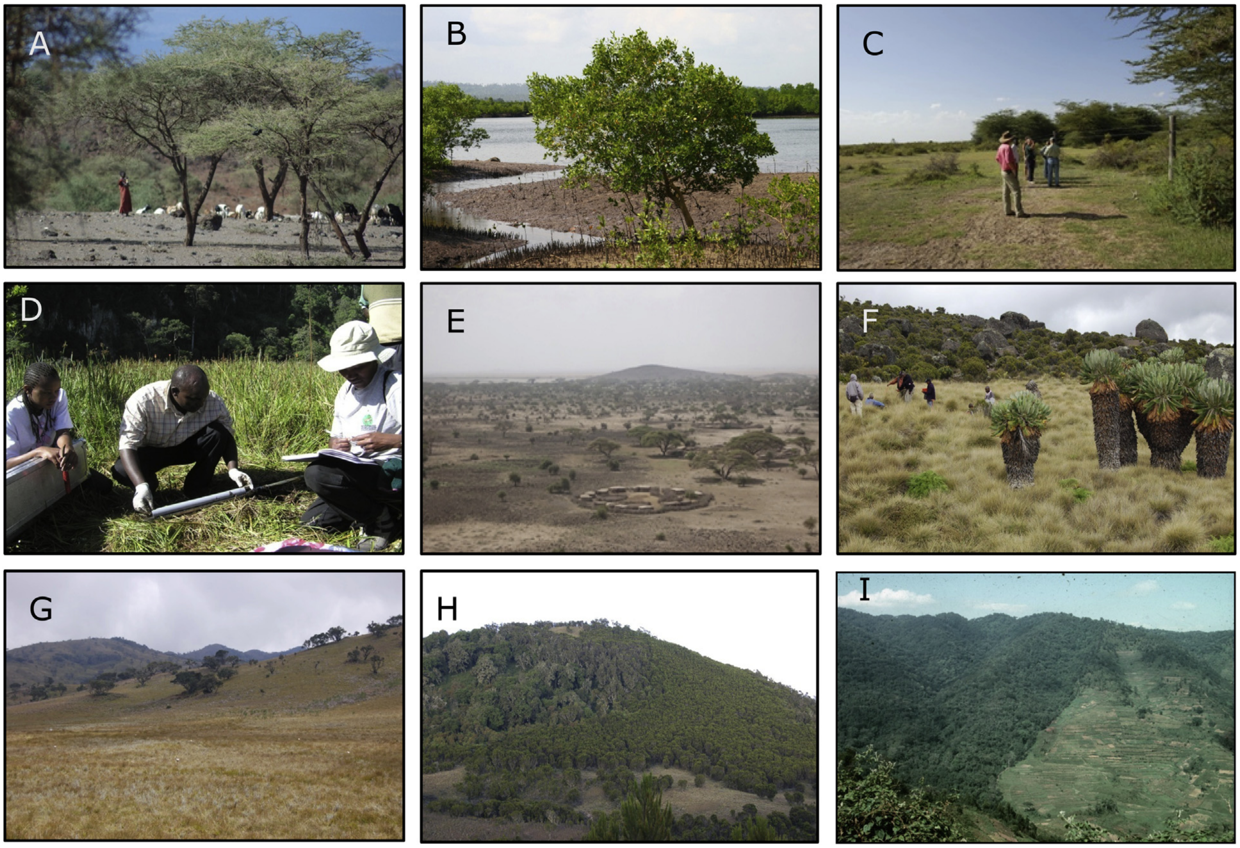

Plate 1. A) Goats are very important in maintaining an open savanna structure and preventing the herb layer and tree seedlings from developing. B) Mangroves form a fringing belt along much of the East African coast and can be locally very extensive. C) Elephants are particularly important in maintaining open dry forest, in this case from Amboseli National Park where the importance of excluding wildlife can be seen by these exclosure plots set up by the African Conservation Centre. D) Collecting sediment cores from Cyperaceae-dominated swamp, in this case Rumuiku Swamp, Mount Kenya. E) Savannas are a product of a long-term interaction with human inhabitation, in this case Massai of the Kenya-Tanzania Borderland region. F) Commonly above ~3800 m grassland ecosystem dominate with locally extensive stands of Scenecio, the plate also shows a newly cored swamp just above the treeline on Mount Kilimanjaro. G) In contrast, the flat plateaux that forms around 2000 m along the Eastern Arc mountains of Tanzania and Kenya also support extensive grasslands – once thought to be anthropogenic in origin recent palaeoecological investigation shows these to be natural and thought to form in response to interactive feedback between local climate, topography and vegetation. H) The density of trees, shrubs and herbs vary massively in space and is particularly influenced by fire in this case Mount Kilimanjaro where a recent fire is marked by a low stature re-growth of Erica arborea. I) Boundary of Bwindi-Impenetrable Forest national Park where agricultural land with high population pressure (c. 500 people km2) border high conservation value montane rainforest and Gorilla habitat. All photographs have been taken by Rob Marchant.

the interlacustrine region that emerged during the early part of the last millennium (Reid, 2013). Forests which were intact at the time of state formation and located towards the outer-limits of the kingdoms' spheres of influence, were 'protected' as a 'natural' deterrent to potential invaders (Taylor et al., 2000). Whatever the result of the cultural contacts between different groups in the Rukiga Highlands we can only suggest what may have occurred as to-date there is relatively little anthropological, historical and/or archaeological information from the region. What is quite obvious from the palaeoecological records is that agricultural land-use spread rapidly after ca. 2000 yr BP with some protection being afforded to Bwindi-Impenetrable Forest. This protection has continued to the present day, now under the guise of National Park legislation, national and international conservation organisations and the world's media.

Parallel to Bwindi-Impenetrable Forest many palaeoecological sampling sites across East Africa *do not* record significant human influences until quite late, if at all, despite archaeological and oral historical evidence for their presence. For example, within the Lake Tanganyika catchment the first evidence of widespread deforestation and increased erosion dates from the late 18th century onwards (Cohen et al., 1997). At Lake Naivasha, maize (*Zea mays*) pollen appears in the record after ~300 cal yr BP (Lamb et al., 2003), at a similar time to South Pare, Tanzania, which is coupled with a reduction of lower montane forest probably as a result of anthropogenic activity and heightened soil erosion in North Pare (Heckmann, 2012). Farther north, on Mount Kenya forest clearance appears to have been quite different to areas in East Africa. Where selective logging has been recorded at other sites in Eastern Africa *Podocarpus* was often a particular focus of forest clearance (Marchant and Taylor, 1998), whereas within the Rumuiku Swamp catchment *Podocarpus* appears to have been preserved and now forms almost mono-specific stands (Rucina et al., 2013). A partial explanation for such a situation may be found in the belief systems and associated agricultural practices of current occupants of Mount Kenya, such as the Kikuyu, whose identify as a distinct ethnicity began to crystallise around AD 1500 (Muriuki, 1974). Specifically, Kikuyu believe trees possess spirits that can interfere in human affairs. To mitigate against the possible harm human intervention may cause, Kikuyu leave a series of large conspicuous trees at regular intervals to absorb spirits from those trees they cut down (Castro, 1991). The most significant of these is the Mugũmu tree (*Ficus natalensis*/*Ficus thonningii*) which symbolises power, life and fertility (Karangi, 2008), but the principle applies also to other species. Alternatively, a more mundane reason, such as leaving these trees to hang bee hives off or to provide a convenient supply

of forest for building and fuel demands, can be used to explain the mono-specific stands of *Podocarpus* on Mount Kenya (Castro, 1991).

Over the long-term, both agriculturalist and pastoralist populations have developed livelihood strategies that fit the ambient environment and variability in this: land use management practices being shaped by the environment leading to the selection and demarcation of territories with a strong sense of place within the landscape (e.g. Bollig and Schulte, 1999). It is these deep-rooted socially constructed connections that have been shown to be most resilient to climate change and the impacts these have on society (Marchant, 2010). Moreover, the extent of human entanglements with plant populations has been so great that few places, if any, in East African can be thought of as truly 'pristine'. This is as much the case for the large areas currently set aside for wildlife conservation, as for seemingly more obviously modified landscapes comprising cultivated fields and gardens or livestock rangelands. Three sets of data support such claims. These are i) the extensive historical documentation and associated oral testimony of forced removals from areas now managed as national parks, such as the Serengeti (e.g. Shetler, 2007); ii) the physical traces of previous human occupation of these areas and utilisation of their natural resources (e.g. Bower and Chadderdon, 1986); and iii) the documented relations of ecological mutualism that have emerged over the centuries in such areas between humans, their domesticates, and wild plant and animal species (e.g. Muchiru et al., 2008a, 2008b).

5. Looking to the future – linking societal and ecological processes

An appreciation of the interlinkages between societal, environmental and ecological processes that underpin livelihoods (Fig. 4) is essential to understanding the nature of human population vulnerability and ecosystem resilience under increasing habitat transformation, fragmentation and human/animal conflicts (Dearing, 2008; Eriksen and Watson, 2009). Societies have evolved and developed under continual climate change with a result that there is often an inbuilt societal resilience to climate fluctuations. If this connection between people and their climatic regime can be understood this resilience can be maximised. To gain such an appreciation requires the abandonment (Hassan, 2000; Costanza et al., 2007; Dearing et al., 2007) of overly deterministic models of the relationships between environmental stress and social change, and their substitution by a new conceptualisation of human–environment interactions as evolving webs of entanglement that stand in a dynamic, recursive relationship to one another. Over time, in much the same manner as Hodder (2011, 2012) has recently argued is the case for the relationships between humans and 'things', so humans and environments need to be seen as perpetually co-constituting each other creating ever more complex chains of interdependence. Humans have long distinguished themselves by using tools and technologies to shape ecosystems (Sereno et al., 2008) and understanding interactions between past ecosystem dynamics, human migration and changing land use strategies has gone beyond the comparison of local records, towards integrative research that can shed light on the dynamic relationship between human societies and climate change (Balée, 2006). However, to rise to the challenges of managing ecosystems in an increasingly populous world we need to fully understand the detail of these relationships, particularly as the very nature of long-term human–ecosystem interaction is rooted in sustainability – resilient ecosystems meeting the needs of past, present and future generations (Stump, 2010). Understanding where these interactions have been successful changes the narrative from one characterised by degradation, disturbance and impacts, to one characterised by abundance, and of ecosystems supporting and developing societies that are interwoven within the ecological fabric of their worlds (Lane, 2009; Marchant, 2010). Thus, the rapid climate change with marked ecosystem responses seen today is not a new phenomenon; the only constant about climate is that it changes, and local responses to such change differ according to feedbacks from topography, substrate and ecoclimatic regime. Past climate variability is much greater than recorded by the instrumental record, and indeed much greater than currently considered by policies on land-use options and livelihoods under climate change scenarios (Conway, 2011). However, most policies operate at the duration of a government (~5 years) with 'forward' thinking national policies such as Vision 2025 for Tanzania only offering scope for approximately 20 years. In ecological terms, and also those of human history, these are relatively short durations which rarely capture the temporal amplitude of the relevant social and ecological drivers of change. Consequently, a much longer term perspective, spanning at least several centuries and with reference to some climatic processes operating over even longer timescales, is essential to developing sustainable future plans, particularly where the natural resilience to buffer climate change impacts has been significantly curtailed by more recent social, political and economic challenges that have altered the boundaries and framework of the human–ecosystem interaction.

Human–ecosystem interactions are inherently dynamic and complex (DeFries et al., 2004). Stemming from the diversity of Eastern African landscapes, ecosystems and cultures, it is apparent that people and ecosystems have responded and adapted to past environmental change in a variety of different ways, and numerous communities have sought to reduce their vulnerability to climate change and variability, allowing them to adapt to and moderate potential shifts, and helping them cope with adverse consequences (Robertshaw et al., 2004). For example, agricultural communities would traditionally turn to more drought-resistant crops such as millet and sorghum, crops that were grown much more extensively prior to the widespread adoption of maize during the 19th and early 20th centuries (Håkansson, 2008). At times, as in the case of the Pokot, different sections have specialised in either herding or agriculture, and by maintaining close reciprocal exchange relationships this has helped them survive periods of extreme climatic stress, such as the major regional drought of the late 18th century (Bessems et al., 2008), far more effectively than some of their neighbours (Davies, 2010, 2012). Similarly, specialised pastoral communities maintain wealth and environmental 'buffers' in herds of cattle; during extreme periods of drought or disease these 'stores' can be massively impacted, as happened for example, among Maasai communities following the Rinderpest epizootic in the late 19th century (Koponen, 1988). This had equally profound consequences for local wildlife populations and thus indirectly also the composition of vegetation mosaics (Dublin, 1991; Spinage, 2012) and even stimulated the resurgence of various disease threats (e.g. Waller, 1990) that previously had been controlled by selective environmental interventions, such as seasonal burning and rotational grazing.

Although, the nature of human–ecosystem interactions is increasingly becoming decoupled from the past, partly due to the unique character of future environments (high atmospheric CO_2, pervasive land-use change and high temperature and high climate variability) it is vital the perspectives and lessons from history are learned and acted upon. This can be more challenging than it may first seem given the rhetoric and overriding political imperative for short-term gain and rapid national development. Consideration of this known ecological response within an environmental-socio-economic modelling framework is necessary to impart effective long-term management strategies that promote the livelihoods of

user communities under changing environmental conditions (Marchant, 2010). Equally, the responsive nature of East African ecosystems to a variable climate, and the dramatic impact these can have on livelihoods needs to be kept in mind, as was emphasised by the regional drought in 2009 that extended across the Horn of Africa decimating herbivore (both domestic and natural) populations and the livelihoods of people living within dry forest ecosystems, especially those on land more marginal for pastoral or agricultural production. We can see from how communities have responded in southern Africa to recent droughts that,x rather than enabling long-term security, an over-reliance on exotic faunal and floral resources can be quite fragile safety nets (Eriksen and Watson, 2009). Whether this was also the case in the past in eastern Africa remains to be explored in detail however.

6. Conclusion

Locations where our understanding of past impacts of environmental change are best constrained, and where the complex interactions between vegetation change, climate and human populations have been clearly documented through time, demonstrate the potential for past perspectives to provide a foundation on which future sustainable development planning can be built. Unfortunately, our understanding of past societal–environmental interaction is limited in both time and space, requiring targeted studies to fill in the gaps, particularly in vulnerable areas. These deficiencies are exacerbated in East Africa where highly diverse ecosystems/environments correlate with great cultural diversity. Such application needs a range of skilled researchers (archaeologists, botanists, economists, historians, palaeoecologists, anthropologists and geographers) who are able to communicate their findings across disciplines and work within a modelling context that connects society and ecosystems (Caseldine and Turney, 2010). For tangible progress to be made, natural and social scientists, and those from historically-oriented disciplines, must overcome language barriers (Ewers and Rodrigues, 2006). This is much more than just semantics – there must be closer interaction between researchers, conservationists, NGOs, and Government agencies (Smith et al., 2009) that actually develop and implement policies based on a solid understanding of ecosystem response to climate change, and public perceptions of these (Ostrom, 2005; Conway, 2011). In order to help human societies face growing environmental challenges ecologists will have to deliver relevant scientific knowledge on ecosystem function and change, how these processes are linked to human well-being and how humankind has transformed them in a sustainable way (Loreau, 2010). This reliance on ecosystem services is exemplified in East Africa by an economically important tourist industry, the importance of agriculture in national economies, the relatively high percentage of electricity generation based on hydroelectricity and the importance of wood fuel for cooking. The degradation of ecosystem services could grow significantly worse during the first half of this century with possible severe consequences for human well-being (Dietz et al., 2009), particularly when viewed in the context of rapidly developing and growing populations. Understanding how changes in the biophysical environment impacted on the flow of these goods and services in the past, the social processes with which they interact, and the manner in which these interactions entrained both humans and ecosystems along particular courses, must form a key focus of any ecosystem management policy. However, this is not trivial and for such an approach to be meaningful understandable metrics are required to demonstrate in unequivocal terms the societal consequences of further degradation of ecosystem services (Mooney, 2010). It is here that the involvement of archaeologists, historians and anthropologists could be vital, as the histories of specific economies or environments are potential sources of positive precedent. For example, there are areas within East Africa where the history, both cultural and environmental, is very well constrained and there is good understanding of the interplay between multiple processes within both the natural and cultural spheres (Lane, 2009). If sustainability can be demonstrated in the past, then this at least suggests the possibility of future sustainability, but the longevity of practices and their environmental consequences must be demonstrated through research and the analysis of empirical data, not just assumed (Stump, 2010). Such huge global challenges as climate change, population growth, biodiversity loss and pressure on ecosystem services demand solutions where nations cooperate in equitable proportions (May, 2010). For such benefits to be truly maximised there is a need for further targeted research as history, both environmental and cultural, is not sufficiently well understood and too diverse spatially and temporally (Stump, 2010) to enable the formulation of simple lessons from the past that can be used to manage the future. However, it is vital that knowledge gaps surrounding natural resource partitioning and ecosystem response to environmental change are filled – this will require truly inter- and intra-disciplinary perspectives, within which palaeoecology and archaeology are integral parts.

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